AS Unit 1: Basic Biochemistry and Cell Organisation

Name:	Date:

Topic 1.2 Cell Structure and Organisation – Page 5

I. Prokaryotic Cells

		Completed
1.	Read about prokaryotic cells such as *Escherichia coli* • Rowlands p. 22 • Toole p • W/S **1.2 I Prokaryotic cells** • W/S **1.2 Iii Prokaryotic cells (Oxford)** Complete the questions at the end of W/S 1.2 I	
2.	Look at the PowerPoint **Comparison of Prokaryotic and Eukaryotic Cells** Make a table that clearly illustrates the differences. Ensure you include details about the following: • Nuclear material • Shape and location of nuclear material • Number of organelles • Membranous organelles • Size • Types of organism that cell types are found in • Ribosomes – location and size • Type of cell division • Cell protection • Sites of respiration and other metabolic reactions	
3.	a.) For each of the following structures outline their role and structure in bacterial cells: • Cell wall • Cell surface (plasma) membrane including invaginations (infoldings) such as photosynthetic membranes and respiratory membranes • Flagella • Bacterial 'chromosomes' and plasmids • Glycogen granules and lipid droplets b.) Be able to draw a simple labelled diagram of a prokaryotic cell.	
4.	Read Handout **1.2L The Origin of Cells** and be in a position to discuss the arguments for and against this theory.	
5.	Complete **WS 1.2K Cell Analogy**	

The Spontaneous Generation Theory

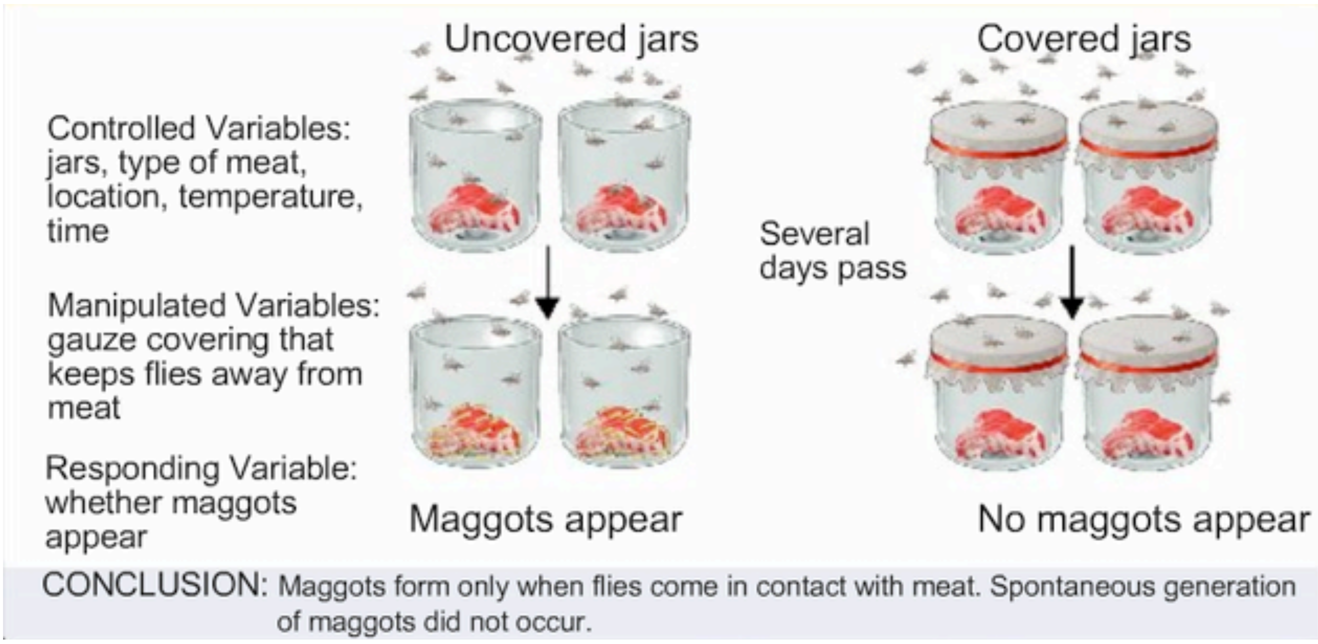
This theory was widely upheld through time by the observation of the appearance of living organisms. The theory suggests that life is spontaneously formed from non-living matter.

The Greek philosopher Theophrastus reported that the plant Silphium suddenly appeared in a place where it had never grown before. He suggested that it had spontaneously appeared there. Aristotle thought that insects arose from the hair, flesh or faeces of animals, and Paracelsus quoted observations of spontaneous generation of mice, frogs and eels.

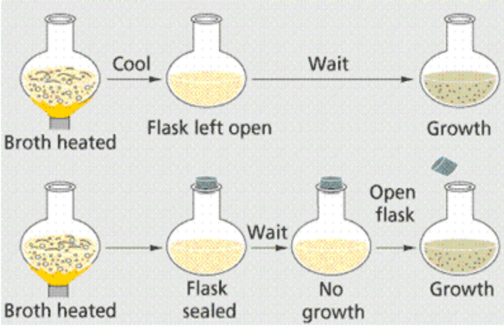
It was very hard for these scientists to see any other reason for the appearance of new organisms when they did not know anything about microbiology, sexual reproduction of the existence of cells.

Three scientists went about disproving the spontaneous generation theory.

Redi left covered and uncovered jars with meat in them. In the uncovered jars, maggots appeared after a few days - much like had been seen over the years. In the covered jars however, no maggots appeared. This diagram below breaks down the "scientific method" for Redi's experiment - showing not only what was done, but explaining each step of the scientific method that occurred.



Spallanzani boiled gravy broth and then left one flask open and sealed another. The boiling process killed off anything that might have already been living in the broth. In the open flask, microorganisms appeared, but in the sealed flask they did not. If spontaneous generation theory was correct, they should have.



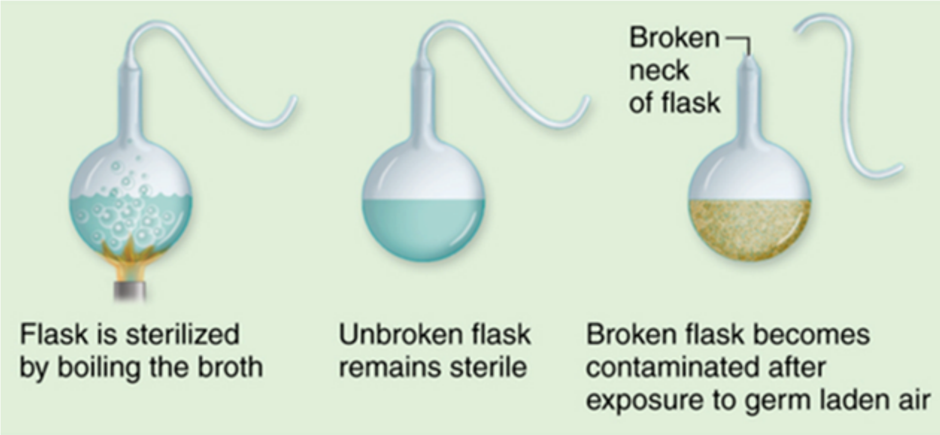
Evidence from Pasteur's experiments that spontaneous generation of cells and organisms does not now occur on Earth.

Louis Pasteur designed an experiment to test whether sterile nutrient broth could spontaneously generate microbial life. To do this, he set up two experiments. In both, Pasteur added nutrient broth to flasks, bent the necks of the flasks into S shapes, and then boiled the broth to kill any existing microbes.

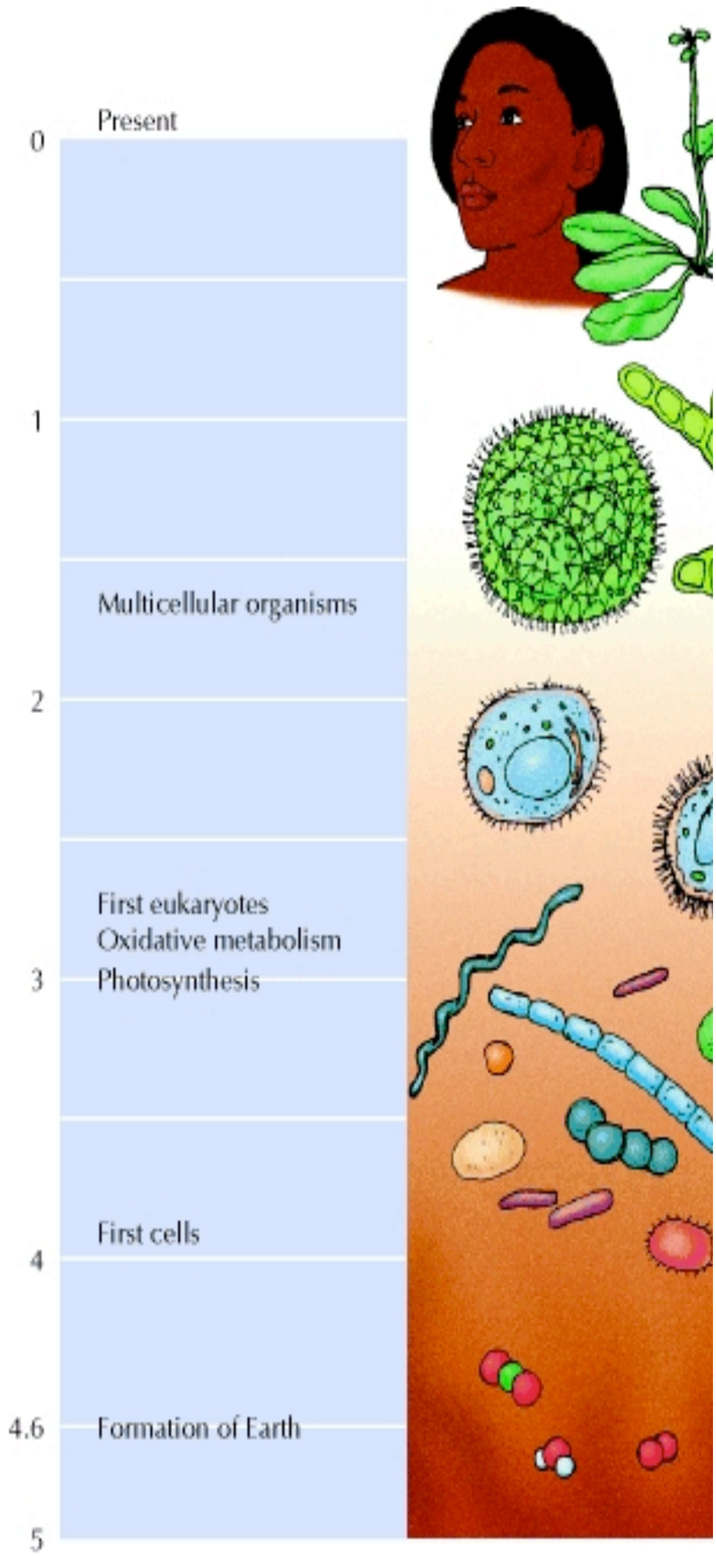
After the broth had been sterilized, Pasteur broke off the swan necks from the flasks in his first experiment, exposing the nutrient broth within them to air from above. The flasks in second experiment were left alone.

Over time, dust particles from the air fell into the broken flasks of experiment 1. In experiment 2, dust particles remained near the tip of the swan necks, but could not travel against gravity into the flasks, keeping the nutrient broth sterile.

The broth in the broken flasks quickly became cloudy--a sign that it teemed with microbial life. However, the broth in the unbroken flasks remained clear. Without the introduction of dust--on which microbes can travel--no life arose. Thus, the Louis Pasteur experiment refuted the notion of spontaneous generation.



Cells are divided into two main classes, initially defined by whether they contain a nucleus. Prokaryotic cells lack a nucleus; eukaryotic cells have a nucleus in which the genetic material is separated from the cytoplasm. Prokaryotic cells are generally smaller and simpler than eukaryotic cells; in addition to the absence of a nucleus, their genomes are less complex and they do not contain cytoplasmic organelles. In spite of these differences, the same basic molecular mechanisms govern the lives of both prokaryotes and eukaryotes, indicating that all present-day cells are descended from a single primordial ancestor. How did this first cell develop? And how did the complexity and diversity exhibited by present-day cells evolve?

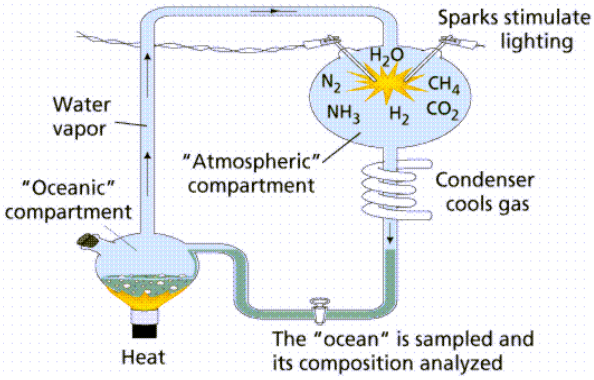


It appears that life first emerged at least 3.8 billion years ago, approximately 750 million years after Earth was formed. How life originated and how the first cell came into being are matters of speculation, since these events cannot be reproduced in the laboratory. Nonetheless, several types of experiments provide important evidence bearing on some steps of the process.

It was first suggested in the 1920s that simple organic molecules could form and polymerize into macromolecules under the conditions thought to exist in primitive Earth's atmosphere. At the time life arose, the atmosphere of Earth is thought to have contained little or no free oxygen, instead consisting principally of CO_2 and N_2 in addition to smaller amounts of gases such as H_2, H_2S, and

CO. Such an atmosphere provides reducing conditions in which organic molecules, given a source of energy such as sunlight or electrical discharge, can form.

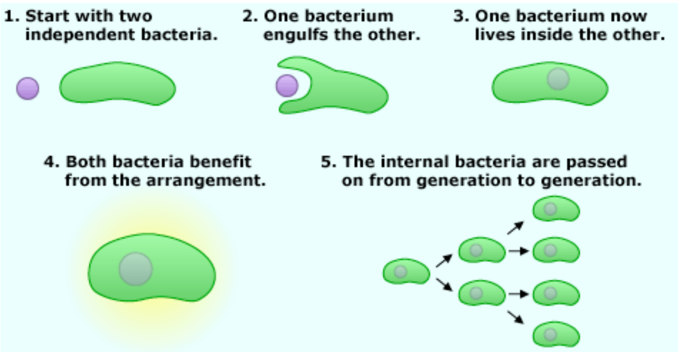
The formation of organic molecules was first demonstrated experimentally in the 1950s, when Stanley Miller showed that the discharge of electric sparks into a mixture of H_2, CH_4, and NH_3, in the presence of water, led to the formation of a variety of organic molecules, including several amino acids. Although Miller's experiments did not precisely reproduce the conditions of primitive Earth, they clearly demonstrated the plausibility of the spontaneous synthesis of organic molecules,
providing the basic materials from which the first living organisms arose.

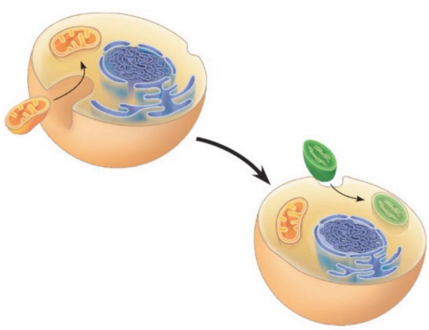


The current theory is that over a long period of time these primitive molecules started to merge and combine to form more and more complex molecules. Eventually membranes, protein and nucleic acids all started to form and combine to become the most primitive cells on Earth later to be called prokaryotic cells.

Endosymbiosis.

The theory of endosymbiosis helps to explain the evolution of the complex eukaryotic cells. It states that mitochondria and chloroplasts were once free-living prokaryotic organisms. They are thought to have been engulfed (endocytosis) into other cells, where they were allowed to stay, grow and divide. The cell that had taken these prokaryotic cells on board got a source of sugars from the photosynthesis, and a way to break down the sugars into ATP molecules.

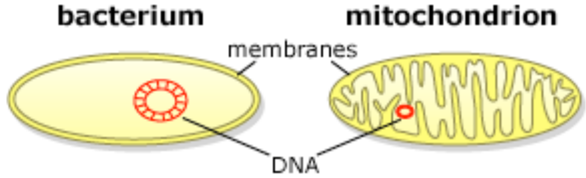
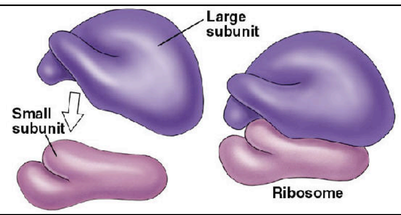
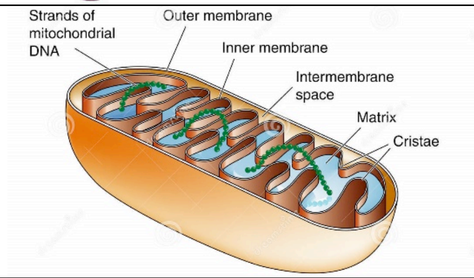
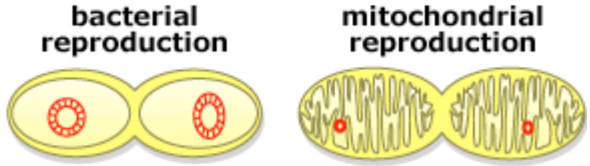


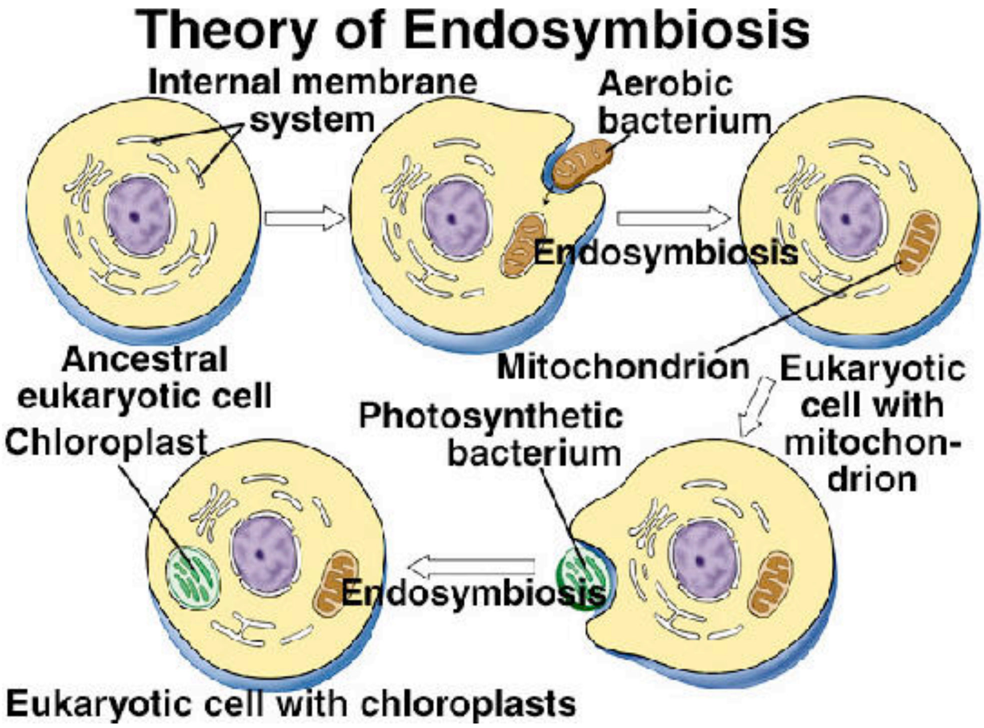


Biologist Lynn Margulis first made the case for endosymbiosis in the 1960s, but for many years other biologists were sceptical. Although Jeon watched his amoebae become infected with the

x-bacteria and then evolve to depend upon them, no one was around over a billion years ago to observe the events of endosymbiosis. Why should we think that a mitochondrion used to be a free-living organism in its own right? It turns out that many lines of evidence support this idea.

Evidence supporting the endosymbiosis theory.

Feature	**Similarity to prokaryotes**	
Presence of DNA	Mitochondria and chloroplasts all have their own circular DNA molecules	
Ribosomes	The protein making ribosomes which are present in mitochondria and chloroplasts are 70S in size.	
Proteins	They transcribe their own DNA into mRNA to make their own proteins.	
Origin	They can only be produced by division of pre-existing mitochondria and chloroplasts.	



Bio Factsheet

September 2000 Number 73

The Prokaryotic Cell

The contents of this Factsheet cover the relevant AS syllabus content of the major examining boards. By studying this Factsheet the candidate will gain a knowledge and understanding of the structure of a prokaryotic cell, the range of prokaryotic organisms and the importances of prokaryotic organisms.

Introduction

Bacteria (eg *Escherichia coli*) and Cyanobacteria (blue-green algae) (eg *Nostoc*) are single-celled and characteristically possess no nucleus. They are prokaryotic organisms.

> ***Remember*** *– the Cyanophyta or blue-green algae are now classed as Cyanobacteria because they are prokaryotic. Algae are all eukaryotic since they possess nucleated cells and cell organelles. In some older textbooks you may still find blue-green algae classed as Cyanophyta. This is now considered to be incorrect and you should refer to them as Cyanobacteria in AS and A2 examinations.*

The prokaryotic cell is the simplest type of living cell. They are relatively small having a diameter in the range of 1 - 5 µm (micrometre), and a volume somewhere between one thousandth and one hundred thousandth of the volume of a typical plant or animal cell. Prokaryotic cells do not have membrane-bound organelles. Remember that a micrometer is 10^{-6} metre.

Form

Prokaryotes show a variety of cell shapes. The three most common are spheres (cocci), rods (bacilli) and spirals (spirilla). Examples of these are shown in Fig 1.

> ***Remember*** *– a light microscope will only show the general shape of bacterial cells and does not have the magnification or resolving power to show the cell contents. To see the ultrastructure of cells, that is, the details of cell contents, an electron microscope is required.*

Ultra-structure

The prokaryotic cell has a **cell wall**, external to the plasma membrane. The wall confers rigidity and maintains the characteristic shape of the cell. It provides physical protection and prevents the cell from bursting in an hypo-osmotic environment in which the cell contents are more concentrated than the external solution. In bacterial cells the wall is 10 - 100 nm (nanometre) thick. (A nanometre is 10^{-9} of a metre). It is made from lipids, polysaccharides and proteins. Most bacterial cell walls contain a unique material called **peptidoglycan**. This compound consists of polymers of modified sugars cross-linked by short chain polypeptides. The specific polymers used vary from species to species. The end result is a net-like multilayered structure. The Blue-green algae have walls similar in structure to some bacteria. Cellulose is not used.

A gelatinous sheath or **capsule**, may be found external to the cell wall. This is found most commonly in blue-green algae. This structure, composed of polysaccharides, absorbs water. The capsule is therefore slimy and serves as a protective layer. (see Fig 2 and 3 overleaf)

Fig 1. Appearance of prokaryotic cells as seen under the high power of a light microscope

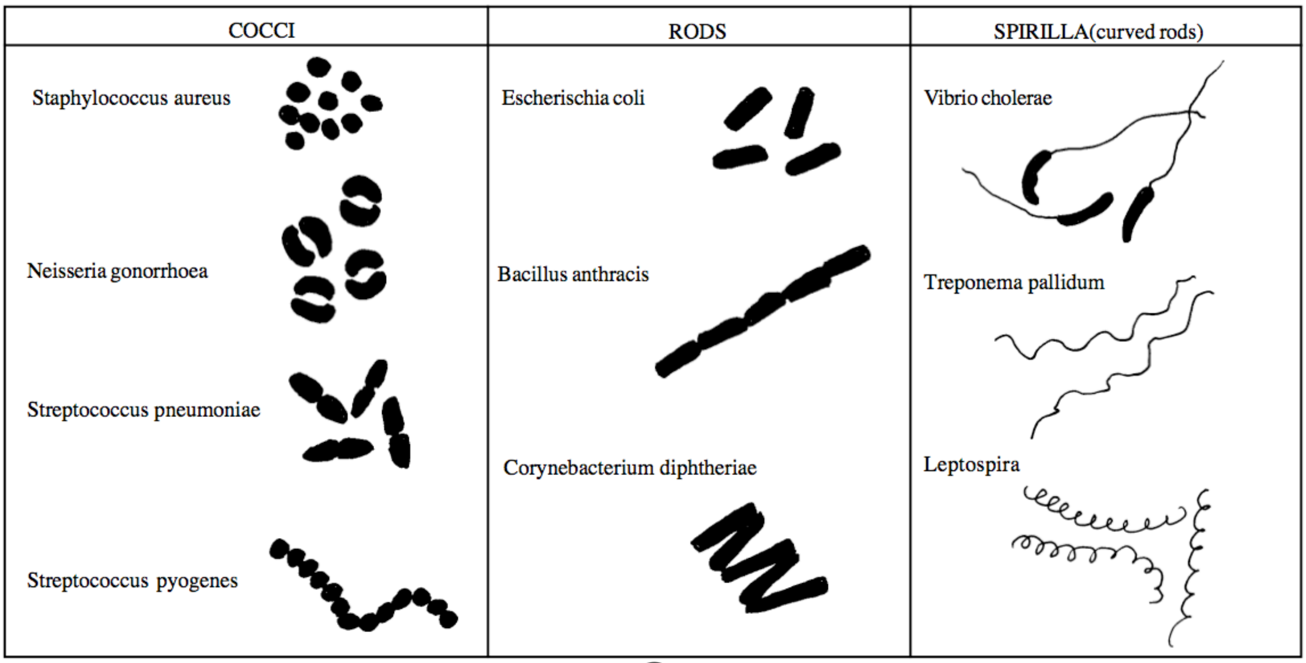


Fig 2 and 3 show the general ultrastructure of a rod-shaped bacterium and a blue-green algal cell.

Fig 2. Ultrastructure of a rod-shaped bacterium

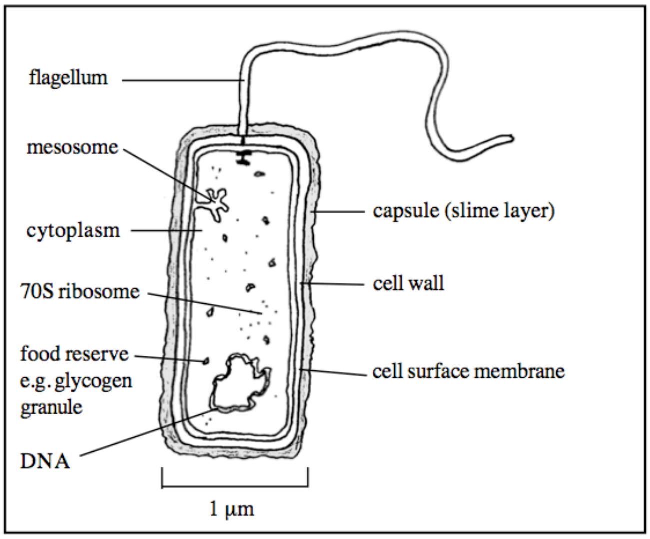
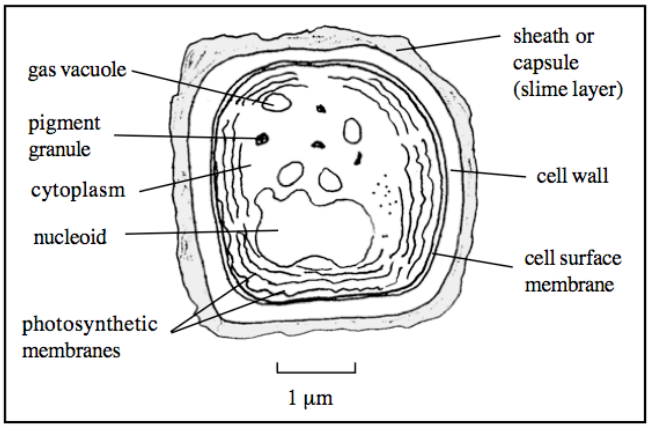


Fig 3. Ultrastructure of a blue green alga



The cell surface membrane, the **plasma membrane,** is composed of phospholipids and proteins. The proteins include enzymes that are involved in respiration, electron transport and nucleic acid synthesis. The membrane is partially permeable and exerts some control over which small molecules and ions can enter and leave the cell.

The cytoplasm of a prokaryote contains storage products (glycogen granules and lipid droplets), ribosomes and plasmids(circular pieces of DNA). The prokaryotic cell is not divided into areas of different function (compartmentalised) by internal membranes. The plasma membrane may however form **invaginations** (mesosomes) , to provide internal membrane surfaces for special purposes; for example, the mesosomes are thought to be the site of respiration.

The feature that makes a prokaryotic cell very different from a eukaryotic cell is its genetic material. The bacterial DNA is in direct contact with the cytoplasm. There is no enclosing membrane and therefore **no recognisable nucleus**. Prokaryotes possess a single, continuous, **circular thread of DNA**. The DNA is located in a region of the cytoplasm called a **nucleoid**. Small structures called **plasmids** may also be present. These carry DNA with only a few genes responsible for special metabolic pathways and resistance to antibiotics. Plasmids can transfer between bacteria and it is this property that has made them important in genetic engineering.

The **ribosomes** found in prokaryotic cells are smaller than those of eukaryotes and are involved in protein synthesis. The rate at which bacteria divide requires a high level of protein synthesis and thus many ribosomes are needed. Thus ribosomes may constitute as much as 40% of the cell mass. Prokaryotic cells possess 70S ribosomes whereas eukaryotic cells possess 80S ribosomes.(S stands for Svedberg units and is a measure of how rapidly the ribosomes sediment in a centrifuge. 80S ribosomes sink quickest because they are heaviest)
Motile bacteria use **flagella** to move. These fibrous projections propel the cell through its environment by rotating clockwise or anticlockwise. The cell movement that results will be in a straight line or in a more uncontrolled, tumbling motion depending on the direction in which the flagellum is rotating.The flagella have a much simpler structure than the complex microtubule flagella of eukaryotic cells.The gas containing vacuoles of blue-green algae are probably for flotation so that the cells remain near the surface of the water and thus receive more light for photosynthesis.

Exam Hint *- Candidates should be able to recognise and describe the features of prokaryotic cells as seen under the electron microscope*

Table 1. Comparison of prokaryotic and eukaryotic cells

Feature	Prokaryote	Eukaryote
Diameter	0.5 - 5µm	up to 40µm
Organisation	Single-celled	Usually part of a tissue
Nucleus	Absent	Present
DNA	Single circular thread	Several linear chromosomes
Phospholipid plasma membrane	Present	Present
Ribosomes	Small 70S	Large 80S
Mitochondria	Absent	Present
Cell wall	Always present made from peptidoglycans (cellulose absent)	Present only in plant cells (cellulose present)

Importances of prokaryotes

1. Chemical cycles

Prokaryotes recycle elements linking the biological and physical components of the ecosystem. They play a significant role as decomposers in the carbon and nitrogen cycles, for example, the nitrifying bacteria *Nitrosomonas* and *Nitrobacter*. Some bacteria function as symbionts, for example, *Rhizobium leguminosarum* in the root nodules of Papilionaceous plants such as clover is important in the fixation of gaseous atmospheric nitrogen. Bacteria such as *Azotobacter* and blue green algae such as *Nostoc* are important free living nitrogen fixing bacteria in the soil.

2. Bacteria and disease

Poisonous chemicals called toxins, released by bacteria, are the most common cause of symptoms of bacterial disease. Toxins released by some types of bacteria may cause disease, even when the bacteria themselves are no longer present. Other types of bacteria produce toxins that are an integral part of the outer membranes of the bacterial cell itself. Both types of pathogen disrupt the natural physiology of the affected individual. Examples of pathogenic (disease causing) bacteria can be seen in Fig 1. For example, Streptococcus pyogenes can cause sore throats and tonsilitis, Bacillus anthracis causes anthrax, Corynebacterium causes diphtheria, Vibrio cholerae causes cholera, Treponema causes syphilis and Leptospira causes leptospirosis(rat borne fever).

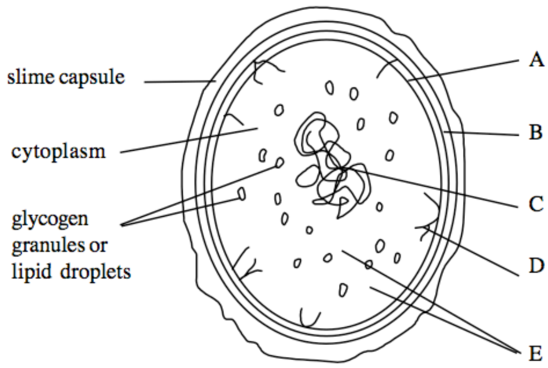
3. Biotechnology
Prokaryotes are useful agents employed in a variety of ways. Examples include:
- use of decomposers in sewage treatment;
- bacterial conversion of milk to yoghurt and cheese;
- manufacture of vitamins and antibiotics;
- use in recombinant DNA technology.

Practice Questions

1. Describe the organisation of genetic material in a prokaryotic cell. 6

2. What are:
   (a) peptidoglycans, 4
   (b) mesosomes, and 4
   (c) plasmids? 4

3. The drawing below shows the ultrastructure of E. coli.



(a) (i) Label structures A to E. 5

(ii) State a function of part D. 1

(iii) What term is given to this bacterial shape? 1

(b) List three ways in which prokaryotic cells differ from eukaryotic cells. 3

Acknowledgements;
This Factsheet was researched and written by David Baylis
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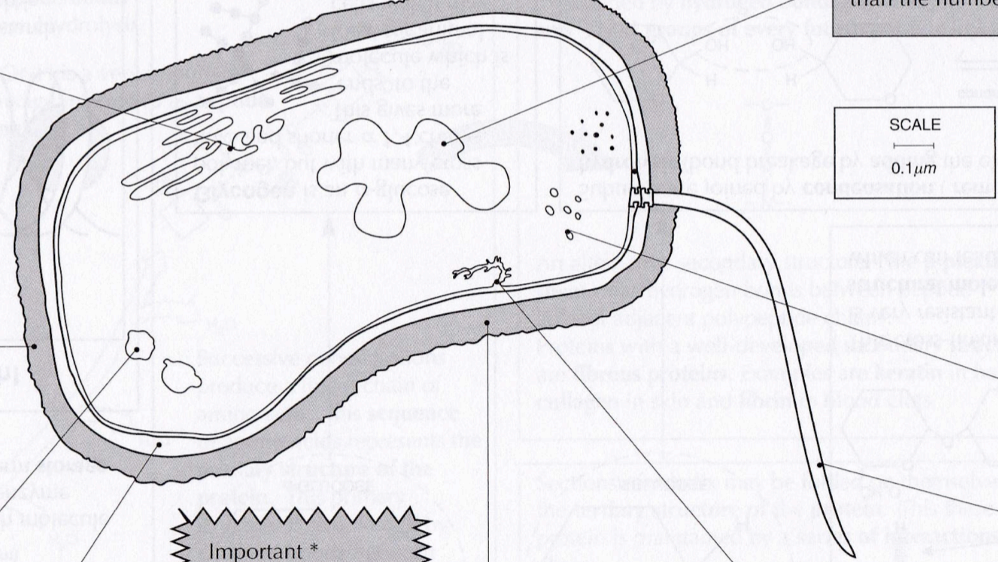
The Cholera bacterium (*Vibrio cholerae*)

is a prokaryotic cell and so has no true organelles.



***Photosynthetic membranes** are surfaces for light-absorbing pigments, but there are no chloroplasts N.B. Bacterial photosynthesis does not evolve oxygen.

Capsule is a gummy layer of mucilage which may join bacteria into colonies (e.g. *Bacillus anthracis*) or give protection (e.g. rough strain of *D. pneumoniae*).

***Plasmids** are short pieces of circular DNA which replicate independently of the cell genome. They have been widely exploited in recombinant DNA technology.

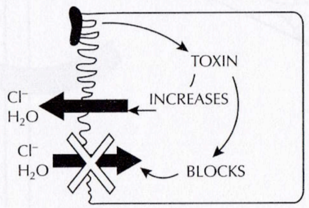
Cell wall has a rigid framework of **murein**, a polysaccharide cross-linked by peptide chains.

Important * comparisons with eukarytic cells.

Oral rehydration solutions (ORS)
These are solutions of ions and glucose. If sufficient is available they can reduce deaths by over 90%. Rice or other cereals in the solution are also very effective at reducing the problems of **dehydration**.

Cholera bacterium causes severe diarrhoea

- The bacterium releases a toxin.
- Toxin increases loss of Cl^- and water.
- Toxin blocks reuptake of Cl^- and water.



Infected person produces very watery faeces (= diarrhoea)

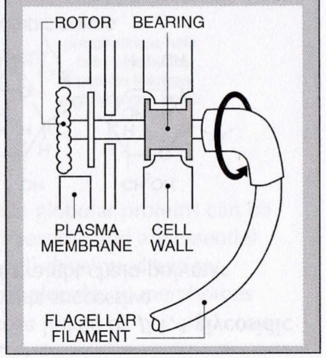
***Genetic material** is composed of a circle of double-stranded DNA **which is not enclosed within a nuclear membrane.** There are typically about 2000 genes, much less than the number found in a eukaryotic cell.

***Ribosomes** smaller than those in eukaryotes. They are scattered throughout the cytoplasm, not supported on an endoplasmic reticulum.

Plasmamembrane is a typical phospholipid bilayer.

Food stores are typically lipid globules or glycogen granules.

***Flagellum** is responsible for motility of many bacteria. It is much simpler than the flagellum of a eukaryotic cell, being composed of a single cylinder of protein subunits (flagellin). The flagellum does not 'beat' but instead rotates about a 'bearing' anchored in the cell wall to produce a corkscrew motion which drives the cell along.



***Mesosomes** are infoldings of the plasma membrane on which the enzymes associated with respiration are located. A proton gradient generated across these membranes is used to drive the synthesis of ATP.

W/S 1.2K Cell City Analogy

In a far away city called Grant City, the main export and production product is the steel <u>widget</u>. Everyone in the town has something to do with steel widget making and the entire town is designed to build and export widgets. The <u>town hall</u> has the instructions for widget making, widgets come in all shapes and sizes and any citizen of Grant can get the instructions and begin making their own widgets. Widgets are generally produced in <u>small shops</u> around the city, these small shops can be built by the <u>carpenter's union</u> (whose headquarters are in town hall).

After the widget is constructed, they are placed on <u>special carts</u> which can deliver the widget anywhere in the city. In order for a widget to be exported, the carts take the widget to the <u>postal office</u>, where the widgets are packaged and labelled for export. Sometimes widgets don't turn out right, and the "rejects" are sent to the <u>scrap yard</u> where they are broken down for parts or destroyed altogether. The town powers the widget shops and carts from a <u>hydraulic dam</u> that is in the city. A large wooden fence encloses the entire city, only the postal trucks (and citizens with proper passports) are allowed outside the city.

Match the parts of the city (underlined) with the parts of the cell.

1. Mitochondria ____

2. Ribosomes ____

3. Nucleus ____

4. Endoplasmic Reticulum ____

5. Golgi Apparatus ____

6. Protein ____

7. Cell Membrane ____

8. Lysosomes ____

9. Nucleolus ____

** Create your own analogy of the cell using a different model. Some ideas might be: a school, a house, a factory, or anything you can imagine**